**The Math Emporium: Higher Education's Silver Bullet**

|  |
| --- |
| **by Carol A. Twigg**  **Change, May/June 2011**  (http://www.changemag.org/Archives/Back Issues/2011/May-June 2011/math-emporium-full.html)  The primary reason many students do not succeed in the [traditional math] course is that they do not actually do the problems. As a population, they generally do not spend enough time with the material, and this is why they fail at a very high rate.  Throughout the 1990's, many people saw information technology as a silver bullet that could solve many of higher education's problems, among them the need to improve learning outcomes and control the ever-upward trajectory of higher education costs. The term “silver bullet” connotes a direct and effortless solution to a problem. Unsurprisingly, the integration of technology and higher education has been neither direct nor effortless, but now we can say with certainty that technology can be used to address both learning and cost problems simultaneously.  One of our most persistent learning problems is the dismal record of student performance in developmental and college-level mathematics at our two- and four-year institutions. But we now know how to improve learning outcomes and student success rates in math at a lower cost than that of traditional instruction—and we can prove it. While not effortless, the solution is as close to a silver bullet as one can get in the complex world of teaching and learning.  Course redesign is the process of re-conceiving whole courses (rather than individual classes or sections) to achieve better learning outcomes at a lower cost by taking advantage of the capabilities of information technology. NCAT has 11 years of experience in conducting large-scale redesign projects in mathematics that do just that. Thirty-seven institutions have been involved, and most have redesigned more than one course either during the project period or afterwards. Collectively, NCAT math redesigns have affected more than 200,000 students to date. Course redesign is not about putting courses online. It is about rethinking the way we deliver instruction, especially large-enrollment core courses, in light of the possibilities that technology offers.  Redesigns in mathematics at NCAT partner institutions have:   * increased the percentage of students successfully completing a *developmental* math course by 51 percent on average (ranging from 10 to 135 percent) while reducing the cost of instruction by 30 percent on average (from 12 to 52 percent), and * increased the percentage of students successfully completing a *college-level* math course by 25 percent on average (from 7 to 63 percent) while reducing the cost of instruction by 37 percent on average (from 15 to 77 percent).   In addition to measuring course-completion rates and cost reduction, all NCAT projects compare student learning outcomes taught in the traditional format with those achieved in the redesigned course. This is done by 1) running parallel sections of the course in the two formats or 2) comparing baseline data from a traditional course to a later redesigned version of the course and looking at differences in outcomes. Assessment techniques include comparing the results of common final examinations, common questions or items embedded in examinations or assignments, pre/post-tests, and final grades when the same assignments, tests, and final exams are used and graded using the same criteria.  From working with large numbers of students, faculty and institutions, NCAT has learned what works and what does not work in improving student achievement in mathematics. The underlying principle is simple: Students learn math by doing math, not by listening to someone talk about doing math. Interactive computer software, personalized on-demand assistance, and mandatory student participation are the key elements of success.  The *emporium model* (named after what the model's originator, Virginia Tech, called its initial course redesign) has been implemented in various ways. Some institutions have large computer labs; others have small ones. At some institutions, students spend a required number of hours in the lab at any time that it is open. At others, instructors meet with students in the lab or in a classroom at scheduled hours. Each institution makes design decisions in the context of the constraints it faces. What is critical is the pedagogy: eliminating lecture and using interactive computer software combined with personalized, on-demand assistance.  **Core Principles: Why Is the Emporium Model So Successful?**  The emporium model has been successful for four reasons:   * *Students spend the bulk of their course time doing math problems rather than listening to someone talk about doing them*.   Mathematics software has been evolving over the last five years, providing more reliable scoring and a better interface for students and instructors. By working with an instructional software package such as ALEKS, Hawkes Learning Systems, or MyMathLab, students are able to spend more time on task than when they listen to a lecture. Students quickly become comfortable with the technology; they especially like the instant feedback they receive when working on problems and the guided solutions that are available when they do not get a correct answer.  The opinion of the faculty leaders who have successfully redesigned math courses is unanimous: students do not learn math by going to lectures. The reason most success rates in math are so low, we believe, is because the three-lectures-per-week approach is simply not appropriate for introductory mathematics courses.   * *Students spend more time on things they don't understand and less time on things they have already mastered*.   In the traditional lecture format, some students are bored because others' questions result in repetition of material they have already mastered, while other students feel overwhelmed by the amount of material covered in each lecture. Moreover, instructional software packages—which include interactive tutorials, computational exercises, videos, practice exercises, and online quizzes—can support auditory, visual, and discovery-based learning preferences.  Through diagnostic assessments for each student, areas of needed practice can be highlighted and individualized study plans developed. When students understand the material, they can move quickly through it and demonstrate mastery. When they get stuck, they can ask for examples or step-by-step explanations and take more time to practice.   * *Students get assistance when they encounter problems*.   Traditional models increase the likelihood that students will get discouraged and stop doing the work because they have no immediate support and don't want to admit before fellow students that they do not understand. So they often do not get answers to the questions they have. In addition, homework problems are typically hand-graded and returned days after the students have made mistakes. By the time they see the graded homework, they are not sufficiently motivated to review their errors.  The emporium model helps students in a variety of ways. Instant feedback lets students review their errors at the time they make them and immediately get assistance from online tutorials and guided solutions, as well as from fellow students. In several of the math emporia, computer stations are arranged in pods of four to six to encourage collaboration. Moreover, instructors, graduate teaching assistants, and/or peer tutors are available to provide individual assistance. Any problem areas are addressed on an individual basis during lab time.   * *Students are* ***required*** *to do math*.   Course redesign succeeds when students participate in scheduled learning activities, yet 30 percent or more may fail to do so. Some institutions have been more successful than others in addressing the issue of non-participating students. Redesign projects have found that students will participate in lab activities and homework *if* they require student participation and *if* they give points for doing so. Students participate more, score higher, and spend longer on course activities when credit is at stake.  At the University of Alabama, the 3.5-hour per week attendance requirement that was in place during the fall 2000 semester was eliminated in spring 2001. Student attendance in the lab declined significantly, and there was an appreciable increase in the number of students who stopped taking tests.  In fall 2001 the requirement was reinstated. Students received course credit for lab time and were penalized if their efforts fell short of the requirement. They were also given the opportunity to erase failing grades on tests by spending a minimum of 10 additional hours in the lab completing assessments on the materials covered by the test. Those changes led to a significant improvement in student performance.  Some institutions recognize that giving course points for attendance increases student engagement and learning but are hesitant to do so because they think it will inflate grades. To determine what effect giving attendance credit had on final grades, Alabama analyzed the grades of 3,439 students in five courses during fall 2005.  Attendance credit had no effect on the grades of 86.8 percent of the students. For 4.5 percent of the students, that credit increased their grade by a plus (e.g., the grade went from a C to a C+). For 0.5 percent, attendance credit allowed them to pass the course. For 1 percent, the credit caused them not to pass the course, and for 7.3 percent, it decreased their grade by a minus (e.g., went from a C to a C-). Thus, the argument that giving attendance credit inflates grades is not supported by the data.  For some faculty, getting rid of classroom meetings implies abandoning the human-interaction side of a classroom and conjures up images of students working alone. Nothing could be further from what happens in a well-designed math emporium. On-demand, personalized assistance is a hallmark of the emporium model. At all institutions using it, personal assistance is available far in excess of that offered in traditional courses.  Academics also tend to confuse using instructional software that includes online tutorials, homework, and quizzes with self-paced online courses. Leaving students on their own doing computer homework without having on-demand tutoring support available is a recipe for disaster. A laissez-faire, unstructured, open-entry/open exit model simply does not work. Students need sufficient structure within a well-articulated set of requirements to succeed.  These core principles have evolved over the last decade based on NCAT's experience in working with hundreds of faculty members and thousands of students. While the basic idea of the emporium was first conceived at Virginia Tech, the original model has been modified and extended in a variety of ways as described below. |

…

|  |  |
| --- | --- |
| **SIX MODELS FOR COURSE REDESIGN**   * Supplemental: Add to the current structure and/or change the content * Replacement: Blend face-to-face with online activities * Emporium: Move all classes to a lab setting * Fully Online: Conduct all (or most) learning activities online * Buffet: Mix and match according to student preferences * Linked Workshop: Replace developmental courses with just-in-time workshops   [**http://www.theNCAT.org/PlanRes/R2R\_ModCrsRed.htm**](http://www.thencat.org/PlanRes/R2R_ModCrsRed.htm)  **FIVE PRINCIPLES OF SUCCESSFUL COURSE REDESIGN**   * Redesign the whole course. * Encourage active learning. * Provide students with individualized assistance. * Build in ongoing assessment and prompt (automated) feedback. * Ensure sufficient time on task and monitor student progress.   [**http://www.theNCAT.org/PlanRes/R2R\_PrinCR.htm**](http://www.thencat.org/PlanRes/R2R_PrinCR.htm)  **FOUR MODELS FOR ASSESSING STUDENT LEARNING**  Establish the method of obtaining data   * Parallel sections (traditional and redesign * Baseline “before” (traditional) and “after” (redesign)   Choose the measurement method   * Comparisons of common final exams * Comparisons of common content items selected from exams * Comparison of pre- and post-tests * Comparisons of student work using common rubrics   [**http://www.theNCAT.org/PlanRes/R2R\_ModAssess.htm**](http://www.thencat.org/PlanRes/R2R_ModAssess.htm)  **COST-REDUCTION STRATEGIES**  Identify the enrollment profile of the course: stable or growing?  Choose the labor-savings tactic(s) that will allow you to implement the chosen strategy with no diminution in quality.   * Substitute coordinated development and delivery of the whole course and shared instructional tasks for the individual development and delivery of each section. * Substitute interactive tutorial software for face-to-face class meetings. * Substitute automated grading of homework, quizzes, and exams for hand grading. * Substitute course management software for human monitoring of student performance and course administration. * Substitute interaction with other personnel for one-to-one faculty/student interaction.   Choose the appropriate cost-reduction strategy.   * Each instructor carries more students by increasing the size or number of sections for the same workload credit. * Change the mix of personnel from more expensive to less expensive. * Do both simultaneously.   [**http://www.theNCAT.org/PlanRes/R2R\_CostRed.htm**](http://www.thencat.org/PlanRes/R2R_CostRed.htm)  **FIVE CRITICAL IMPLEMENTATION ISSUES**   * Prepare students (and their parents) and the campus for changes in the course. * Train instructors, graduate teaching assistants, and undergraduate peer tutors. * Ensure an adequate technological infrastructure to support the redesign as planned. * Achieve initial and ongoing faculty consensus about the redesign. * Avoid backsliding by building ongoing institutional commitment to the redesign.   [**http://www.theNCAT.org/PlanRes/R2R\_Imp\_Issues.htm**](http://www.thencat.org/PlanRes/R2R_Imp_Issues.htm)  Each institution made several key modifications to the model used by four-year institutions:   * *A “fixed” or “fixed/flexible” version of the emporium*. In all versions, mandatory attendance (e.g., a minimum of three hours weekly) in a computer lab or classroom ensures that students spend sufficient time on task and receive on-demand assistance when they need it. At four-year institutions, a flexible version of the emporium has predominated: While a minimum number of lab hours are mandatory, they may be completed at the student's convenience. JSCC implemented a fixed version where instructors meet with student cohorts in the lab at scheduled times. CSCC developed a fixed/flexible version—that is, the three mandatory hours working with software are a combination of one fixed meeting in a computer classroom, one flexible hour in the lab, and one additional hour spent working from anywhere (e.g., from home.) * *Modularization*. The Tennessee community colleges redesigned multi-course sequences and introduced modularization as an additional innovation. Both CSCC and JSCC replaced the developmental math three-course sequence with a modularized curriculum mapped to the competencies originally required in the three courses. Students are required to complete one module satisfactorily before moving on to the next, and they can begin the next semester with the next required module not completed during the previous semester. The multi-entry and multi-exit opportunities and individualized pacing permit students more frequent opportunities for successful completion and more time to focus on deficiencies. Students can progress through content modules at a faster or slower pace, depending on the amount of time they need to master the module content. * *Mastery learning*. Both institutions combined a modularized curriculum with a mastery-based learning strategy. Before students can move from one homework assignment to the next, they are required to demonstrate mastery (70 percent at CSCC and 80 percent at JSCC.) After all homework for a module is completed, students take a practice test as many times as needed.   Once ready, students take an online proctored post-test that comprises 70 percent (CSCC) or 75 percent (JSCC) of the module score. Unsuccessful students can ask for help before retaking the test. The remaining portion of the module score, which has to be at least 75 to complete the module, is for attendance, notebooks, and homework.  **Core Principles: Why has the Emporium Model Been Sustained?**  In a June 9, 2008 *Inside Higher Ed* article, Vincent Tinto declared, “We must stop tinkering at the margins of institutional life, stop our tendency to take an ‘add-on’ approach to institutional innovation, … stop marginalizing our efforts and in turn our academically under-prepared students, and take seriously the task of restructuring what we do.”  Most reformers in mathematics are simply tinkering at the margins without a clear vision of how to create significant and sustainable change. NCAT and its partner institutions have proven that redesigning both developmental and college-level math using the emporium model results in dramatic increases in student success and reductions in instructional costs. Furthermore, we have done so with very large numbers of students over a ten-year period. Institutions like Virginia Tech and the Universities of Alabama and Idaho have taught thousands of students for a decade in this new mode. NCAT redesigns have moved well beyond the experimentation stage; they have been both scaled and sustained.  We believe that the following characteristics of redesign directly contribute to that scalability and sustainability and are key differentiators between NCAT redesigns and other reform efforts in math education.   * *Whole-course redesign conducted by teams of faculty and administrators*. Innovations in higher education frequently fail because they are dependent upon a single champion—a risk-taking, creative faculty member or administrator who is trying to create change within the institution. If that champion leaves the institution or changes positions within it, there goes the innovation. “Random acts of progress,” as Bill Graves has called them, frequently produce good results but rarely lead to sustained change.   In contrast, NCAT course-redesign teams include many faculty and administrators who follow a redesign plan that is fully supported by the entire department. In each NCAT redesign, the whole course rather than a single class or section is the target of redesign. In contrast to traditional courses, where each instructor typically does his or her own thing, redesigned courses are consistent in content, coverage, assessment, and pedagogy across all sections. The redesign becomes “institutionalized,” making the innovation relatively impervious to individual shifts in personnel. A collective commitment to redesign the whole course is key to sustainability.   * *Proven methods of integrating technology and learner-centered pedagogy*. Innovations in higher education that focus on materials creation rather than how the materials are used frequently fail. Successful course redesign that improves student learning while reducing instructional costs is heavily dependent upon high-quality, commercially available learning materials such as ALEKS, Hawkes Learning Systems, or MyMathLab, which play a central role in engaging students with course content. Faculty members who incorporate commercially available materials are able to focus on pedagogical and organizational issues rather than on materials creation, adaptation, and maintenance. Redesign teams can also rely on commercial providers for training, support, and software maintenance.   But it's not the software itself that's critical to success; it's the way the software is used. Most attempts to use technology in mathematics reform are simply “add-ons” to an otherwise unchanged instructional process. Students continue to meet in traditional classroom settings with teacher-led activities at fixed times and places, and technology is used as a supplement, typically outside of class as homework, and often as a suggestion rather than a requirement.  NCAT redesigns make student use of software coupled with on-demand, individualized assistance a centerpiece of their pedagogical strategies. Rather than leaving it up to individual instructors to decide whether and how to use instructional software, these redesigns coordinate the efforts of all course instructors so that all students receive a uniform, high-quality learning experience.   * *Cost reduction as an integral part of the redesign*. Unfortunately, many innovations in higher education rely on internal or external grant funding in order to exist rather than to support the transition to a sustainable model. Increased student success may be temporarily achieved due to extra resources provided by the grant, but when the funding ends, so does the innovation. In contrast, in every successful NCAT redesign, the cost of offering the course is reduced. Institutions that have increased learning at a reduced cost have no motivation to return to a less-successful, more-expensive approach. Each redesign includes sustainability in its plan from the outset, and no new resources are needed on a recurring basis to sustain the redesign.   **Conclusion**  In a 1994 *Educom Review* article, Robert C. Heterick, Jr., former president of Educom, wrote:  *Lord Kelvin once made the observation, “If you can measure that of which you speak and express it in numbers, you know something about your subject; but if you cannot measure it, your knowledge is of a very meager and unsatisfactory kind.” If he is correct, then our knowledge about how, and to what extent, the use of information technology in teaching and learning affects outcomes—both learning and cost—is meager indeed.*  *One of our continuing tasks must be to measure, hypothesize, and finally formalize theories about how technology applies to the educational enterprise. One of our great failings as a community consists of relying too heavily on the anecdotal and not doing the hard work of “proving” our concepts through meticulous measurement and theory building.*  *If, as many of us are already convinced, information technology will be the lever that dramatically repositions the learning enterprise in our society, then we have a truly formidable task ahead of us in selling a significant reallocation of institutional resources away from personal mediation and toward technology mediation. Absent well-documented measurements of how much learning for how much resource, we can expect to see a continuation of the pursuit of academic quality that is indifferent to cost.*  NCAT's work over the past 11 years has been inspired by these ideas and has tried to live up to this standard.  Clearly the implications for colleges and universities around the country of the outcomes produced by the colleges and universities cited in this article are substantial. By putting students first and organizing their redesigns around the individual needs of students rather than the convenience of institutions, these pioneering institutions are making a major contribution to improving the ways in which all of us help students succeed in college and move more rapidly to degree completion.  I recently wrote to John Squires, the project leader at Cleveland State, to congratulate him and his colleagues on their outstanding work. I said, “You guys are the poster children for how to do the right thing! You should be really proud.” John's response: “Much of what we did is simply follow the NCAT playbook.”  That playbook is the product of the hard work and dedication of many extraordinary faculty and staff around the country who are showing the way to address one of our country's most vexing academic problems. The message is simple: Students learn math by doing math, not by listening to someone talk about doing math.  Carol A.Twigg ([**ctwigg@theNCAT.org**](mailto:ctwigg@theNCAT.org)) is president and CEO of the National Center for Academic Transformation (NCAT), an independent, not-for-profit organization dedicated to the effective use of information technology to improve student learning outcomes and reduce costs in higher education. Since 1999, NCAT has conducted four national and five state-based course redesign programs, producing more than 120 large-scale redesigns that achieve quality enhancements as well as cost savings. Participating institutions include research universities, comprehensive universities, private colleges, and community colleges. Course redesigns focus primarily, but not exclusively, on large-enrollment, introductory courses in multiple disciplines, including 16 in the humanities, 60 in quantitative subjects, 23 in the social sciences, 15 in the natural sciences and six in professional studies.  [**Read Comments**](http://www.changemag.org/Comment%20on%20Recent%20Articles) **|** [**Submit Your Comment**](http://www.changemag.org/Comment%20on%20Recent%20Articles/)  [**[Subscribe](http://www.changemag.org/Subscribe/subscribe.html)Become a Subscriber**](http://www.changemag.org/Subscribe/subscribe.html) **| Access for Current Subscribers**[**Access for Current Subscribers**](http://www.informaworld.com/VCHN) | In this Issue   * [Academic Standards: The British Experience](http://www.changemag.org/Archives/Back%20Issues/2011/May-June%202011/the-british-experience-abstract.html) * [American Higher Education: “First in the World”](http://www.changemag.org/Archives/Back%20Issues/2011/May-June%202011/first-in-the-world-full.html) * [Books Worth Reading](http://www.changemag.org/Archives/Back%20Issues/2011/May-June%202011/books-worth-reading-abstract.html) * [Complex Systems, Interdisciplinary Collaboration, and Institutional Renewal](http://www.changemag.org/Archives/Back%20Issues/2011/May-June%202011/institutional-renewal-abstract.html) * [Editorial: Research for Action](http://www.changemag.org/Archives/Back%20Issues/2011/May-June%202011/research-for-action-full.html) * [Evidence and Impact: How Scholarship Can Improve Policy and Practice](http://www.changemag.org/Archives/Back%20Issues/2011/May-June%202011/evidence-and-impact-abstract.html) * [How Robust Are the Findings of Academically Adrift?](http://www.changemag.org/Archives/Back%20Issues/2011/May-June%202011/academically-adrift-abstract.html) * [In Search of a New Developmental-Education Pedagogy](http://www.changemag.org/Archives/Back%20Issues/2011/May-June%202011/education-pedagogy-abstract.html) * [Letter to the Editor: May/June 2011](http://www.changemag.org/Archives/Back%20Issues/2011/May-June%202011/letter-to-the-editor.html) * [Listening to Students: Looking Back, Looking Forward](http://www.changemag.org/Archives/Back%20Issues/2011/May-June%202011/listen-to-the-student-abstract.html) * [Plus Ça Change: A Fascination with Plumbers](http://www.changemag.org/Archives/Back%20Issues/2011/May-June%202011/plus-ca-change-full.html) * [The Math Emporium: Higher Education's Silver Bullet](http://www.changemag.org/Archives/Back%20Issues/2011/May-June%202011/math-emporium-full.html)   On this Topic   * [The Math Emporium: Higher Education's Silver Bullet](http://www.changemag.org/Archives/Back%20Issues/2011/May-June%202011/math-emporium-full.html) * [Leveraging the NSF Broader-Impacts Criterion for Change in STEM Education](http://www.changemag.org/May-June%202009/abstract-broader-impacts.html) May/June 2009 (Abstract) * [Addressing the Crisis in College Mathematics: Designing Courses for Student Success](http://www.changemag.org/Archives/Back%20Issues/July-August%202008/abstract-college-mathematics.html) July/August 2008 (Abstract) |